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9 authors, including:

Palash Kundu
Jadavpur University

Sheikh Maniruzzaman
Bangladesh Rice Research Institute

Sanjoy Kumer Debsharma
Bangladesh Rice Research Institute

Md Hasibur Rahaman Hera
Bangladesh Rice Research Institute

North American Academic Research

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Research

Rainfall Induced Saline Soil Management through Leaching

Palash Kumar Kundu[1*], Md. Ferdous Parvez[2], Dr. Tapos Kumar Acharjee[3], Sheikh Maniruzzaman[1] , Sanjoy Kumar Debsharma[1], Golam Sarwar Jahan[1], Hasibur Rahaman Hera[1], Aishik Debnath[1], Md. Rezoan Bin Hafiz Pranto[1]

[1] *Scientific Officer, Bangladesh Rice Research Institute, Gazipur, Bangladesh*

[2] *Lecturer, EXIM Bank Agricultural University Bangladesh, Bangladesh*

[3] *Associate Professor, Bangladesh Agricultural University, Mymensingh, Bangladesh*

[*]***Corresponding author:***

kundu22_bau@yahoo.com

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Abstract: *This study was conducted in the experimental farm of Bangladesh Agricultural University (BAU) to evaluate rainfall-induced leaching of salt in the field soil over time. There were five treatments – I_1: soil irrigated with fresh water, I_2: soil irrigated with saline water of electrical conductivity (EC) = 4 dS/m, I_3: soil irrigated with saline water of EC = 7 dS/m, I_4: soil irrigated with saline water of EC = 10 dS/m, and I_5: soil irrigated with saline water of EC = 13 dS/m. The treatments were replicated thrice. Soil samples were collected from each plot at 0–20, 20–40, 40–60 cm soil profiles at, usually, 15 days interval. By determining the electrical conductivity of the samples salt leaching pattern in the treatments at different depths was evaluated. Variation of soul pH was also evaluated. At the end of the rainy season, the salt accumulated due to irrigation completely leached out of the top 0–20 cm soil profile in all treatments. The salt from the upper soil profile (0–20 cm) leached down and increased the salinity of the lower soil profiles. At the end of the rainy season, the salinity in the lower soil profile did not reduce to its initial value, implying that the rainfall was not enough to wash out the imposed salinity from the entire root zone soil. At the early period of rainy season, the rainfall was relatively little, but the rate of EC reduction was high, especially in the soil with high salinity (treatments I_4 and I_5). At the later period, on the other hand, the EC reduction rate was relatively low although rainfall was high. It is concluded that, irrigation with high saline water (EC ≥7 dS/m) caused accumulation of salt in excess of that washed out by monsoon rainfall.*

Keywords: rainfall, leaching, salinity, pH, saline soil management.

Introduction

Soil salinity is the foremost challenge facing by the agriculture sector in many countries of the world as well as in Bangladesh. One-fifth of irrigated lands all over the world are salt-affected and salinity is occurring at a rate of 1.5 million hectares per year resulting in making the alarming prediction of losing 50% of cultivable lands by 2050 [1]. Soil salinity is a serious constrain to sustainable crop production especially in the arid and semi-arid regions of the world. In these regions, fresh irrigation water is decreasing with time. These areas are affected by various degrees of soil salinity. In order to overcome water scarcity many countries have adopted the use of marginal water especially for irrigation [2]. Irrigation with saline water is successfully practiced today in many countries such as Tunisia, India, Egypt, Israel and US [3]. The agriculture sector must utilize the land resources effectively for increasing the production to meet the demand of the country. But soil salinity is a major constraint to the effective use of the land since a lot of land is affected by salinity in Bangladesh especially at the southern part of the country. To meet the demand of the population, Bangladesh must increase food production in saline area. There are two ways to grow crops successfully in salt-affected area. The first one is to identify the salt tolerant crop varieties and the second one is reclamation of salt affected land. But reclamation practices are expensive and require continuous management [4]. Rainfall may, however, help in reclamation of saline soil. To exploit the washing effect of rainfall, a good understanding of the reclamation process of saline soil is required.

Salinity is the presence of soluble salts in soils or waters. It is a general term used to describe the presence of elevated levels of different salts such as sodium chloride, magnesium and calcium sulfates and bicarbonates, in soil and water. Salinity problem can occur on irrigated land particularly when irrigation water quality is marginal or worse. The reasons for salinity are: (a) use of saline irrigation water, (b) depositions of salts on soil surface from high sub-soil water table, (c) seepage from canals, (d) arid climate, (e) poor drainage, (f) back water flow or intrusion of sea water in coastal areas. [5]

Currently, in Bangladesh, 1.056 million hectares of land is affected by salinity of various degree [6]. In these areas, the range of salinity is categorized on the basis of electrical conductivity (EC) between 2 to 16 dS/m. The severity of salinity problem in Bangladesh increases from November to May with the desiccation of the soil when concentration of salts in the soil surface builds up by rapid evapotranspiration. During the wet monsoon, the severity of salt injury is reduced due to dilution of the salt in the root zone of the standing crop. The lands can be made productive by preventing the recharge of saline water, leaching the salts out of the root zone and correcting toxicity and nutrient deficiency in plant through salt amendments.

Improvement of a saline soil implies the reduction of the salt concentration of the soil to a level that is not harmful to the crops. To that end, more water is applied to the field than is required for crop growth. This additional water infiltrates into the soil and percolates through the root zone. During percolation, it takes up part of the salts in the soil and takes these along to deeper soil layers. In fact, the water washes the salts out of the root zone. This washing process is called leaching. Some chemicals may also be used to control salinity, but this is usually very costly especially when in a large area of land reclamation is needed. In rainy season, in a heavy rainfall area, a lots of water passes through the soil. The relation between reclamation of saline soil and the amount of rainfall with time is yet not well known. There is currently no such evidence of comparing reclamation with the rainfall and the gradual improvement of salinity condition of a soil with time.

Therefore, considering the present situation of world's agriculture, now it is important to study on the reclamation process of the saline soils so that proper efforts can be initiated at the field level to increase available cultivable area. Where high rainfall occurs during rainy season, we may take the advantage of leaching of saline soil due to rainfall. Thus, considering the scope of this research work, this study was planned with the following objectives: to quantify rainfall-induced leaching of salt through field soil, to correlate salt leaching with rainfall, and to identify depth variation salt leaching due to rainfall.

Materials and methods

The experiment was done at the experimental field of the Department of Irrigation and Water Management (IWM) of Bangladesh Agricultural University (BAU), Mymensingh, during the month of March to October, which is located in the Old Brahmaputra Floodplain (Agro-Ecological Zone 9) that lies at 24.75^{o}N latitude and 90.50^{o}E longitude. The elevation of the experimental site was 18 m above mean sea level. The soil the soil was silt loam underlain by sandy loam texturally. The top soils were moderately acidic but sub-soils were neutral in reaction. The organic matter content of the experimental soil was low (0.48%). The sub-tropical climate of the experimental site is characterized by high temperature, high humidity and an above average rainfall of 2451 mm with occasional gusty winds in kharif season (April−September). The rabi season (October−March) is characterized with occasional and less rainfall associated with moderately low temperature. In a previous field experiment, saline water of different salinity levels, prepared by mixing sodium chloride (NaCl) salt with water from a deep tube well, was applied in an experiment with wheat cultivation during the period from November to March. The experiment consists with only one factor, soil with different salinity levels, which had five treatments and three replications. The treatments (replicated three times consecutively) were:

(i) I_1: Soil irrigated with fresh water,
(ii) I_2: Soil irrigated with saline water of EC=4 dS/m,
(iii) I_3: Soil irrigated with saline water of EC=7 dS/m,
(iv) I_4: Soil irrigated with saline water of EC=10 dS/m, and
(v) I_5: Soil irrigated with saline water of EC=13 dS/m.

Each block was divided into 5 unit plots having 3m x 2m size. A buffer of 1m between the adjacent blocks, and 0.5 m between the adjacent unit plots were maintained. There were total 15 unit plots. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications ($R_{1,}$ R_2 and R_3). The five irrigations treatments (irrigation water of different salinity levels) were employed. Soil samples were collected from each plot by using a hand auger. The samples were collected at 20 cm increments to a depth of 60 cm considering the effective root zone of wheat as 60 cm. The samples were collected, in general, at 15 days interval, starting from just after harvesting of wheat until the end of rainy season (March–October); there was no rainfall between harvesting and first soil sampling. During heavy rainfall in July–August, there was standing water in the field, soil samples were collected at one month interval. These samples were transferred to the soil and water engineering laboratory of IWM department, dried in air and sieved through a 2-mm square mesh sieve. The samples were stored in separate polythene papers for analysis. Undisturbed soil samples were also collected in 5 cm × 5 cm core samplers to determine bulk density and field capacity. The textures of the soils at the three depth intervals were determined by Hydrometer method. The bulk density and field capacity of the soils were determined in this study. The physical properties of the soil, determined at laboratory, are listed in Table 2.1.

The EC and pH of the soils were determined by using a combine electrical conductivity and pH meter. For this determination, 30 g of air-dry soil was taken into separate conical flasks of 100 ml capacity, and 75 ml distilled water was added with each soil. The ratio of soil and water was 1:2.5. The soil-water mixture was shaken by using a shaker at 250 rpm for 15 minutes. Then, the conical flasks were kept undisturbed for six hours for sedimentation in a control room at 25°C. The saturation extract were separated from the saturation paste carefully by filtration. The EC and pH of the saturation extract were measured by the combined conductivity and pH meter.

Table 2.1. Some physical properties of the soil at different layers of the experimental field.

SD*	PSD*			γ_b *	TC*	FC*
	Sand	Silt	Clay			
0-20	32.58	56.66	10.76	1.26	Silt loam	39.10
20-40	54.57	40.0	5.43	1.35	Sandy loam	38.62
40-60	67.91	26.67	5.42	1.40	Sandy loam	36.85

*[SD= Soil depth (cm), PSD=Particle Size Distribution (%), γ_b=Bulk density (g/ cm3), TC= Textual Class, FC= Field Capacity(%)]

There were different amount of salts in the soil under different treatments. Due to rainfall, the soil salinity changed over time as a function of depth. By analyzing the measured EC and pH, the temporal and spatial dynamics of the salt in the soil were evaluated.

Results:

Rainfall-induced leaching of salt through field soil over time was measured, analyzed and interpreted. The results have been summarized in tables and graphs. The findings have been presented, discussed and interpreted in this chapter.

Initial soil salinity and pH

The experimental plots under investigation received irrigation with different salinity levels. So, each treatment had specific initial salinity as given in the Table 3.1.

Table 3.1. Average initial soil salinity under different treatments at different depths.

Treatments	**Soil EC (dS/m) at depth**			**Soil pH at depth**		
	0-20 cm	**20-40 cm**	**40-60 cm**	**0-20 cm**	**20-40 cm**	**40-60 cm**
I_1	0.14	0.10	0.11	7.89	7.96	8.13
I_2	0.69	0.36	0.11	7.88	7.87	8.11
I_3	0.86	0.54	0.12	7.99	8.12	7.96
I_4	1.14	0.61	0.32	7.79	7.82	7.91
I_5	1.50	0.74	0.33	7.65	7.92	7.96

The initial soil salinity was very low (negligible to affect crop production) in treatment I_1, due to irrigation by fresh water. The small amount of salinity was due to the antecedent chemical compounds and soil clay contents, which are responsible for some degree of electrical conductivity. The initial soil salinity was relatively high in treatment I_2 and it gradually increased in the other treatments. This was because these treatments were irrigated by water of gradually higher salinity. The initial soil salinity was the highest for treatment I_5. Also, the initial soil salinity was higher in 0-20 cm soil profile than 20-40 cm and 40-60 cm soil profiles. Soil salinity in 20-40 cm profile was also higher than in the 40-60cm profile. The initial pH values of the soil at different depths under different treatments are compared in Table 3.2. It is observed that the pH of the soil at all depths and in all treatments is mostly of similar magnitude. No noticeable and systematic effect of salinity is evident. The pH levels in the soil were in the alkaline range.

Table 3.2. Average initial soil pH at different depths under different treatments.

Treatment	Soil pH at depth		
	0-20 cm	20-40 cm	40-60 cm
I_1	7.89	7.96	8.13
I_2	7.88	7.87	8.11
I_3	7.99	8.12	7.96
I_4	7.79	7.82	7.91
I_5	7.65	7.92	7.96

Salt leaching by rainfall

Due to rainfall, salt leaching occurred and it was found that the leaching pattern varied for different treatments and different depths.

Salt leaching over time

The pattern of salt leaching at 0-20 cm soil profile under different treatments is illustrated in Fig.3.1. This figure demonstrates that treatment I_1 had very low salinity, which did not change over time. But, other treatments had high salinity, which decreased with time through rainfall-induced leaching. Treatment I_2 having lower salinity than treatment I_5 at the initial state released its salt quickly than did I_5. In treatment I_5, initially the salt leaching rate was very high, but it decreased with time. At the end of the rainy season, the salt accumulated due to irrigation completely leached out of the top 0-20 cm soil profile. Figure 3.2 illustrates the pattern of salt leaching at 20-40 cm soil profile under different treatments. Treatment I_1 always had the lowest salinity, and with time, its salinity level did not change noticeably. The other treatments were of high salinity that decreased with time through rainfall-induced leaching.

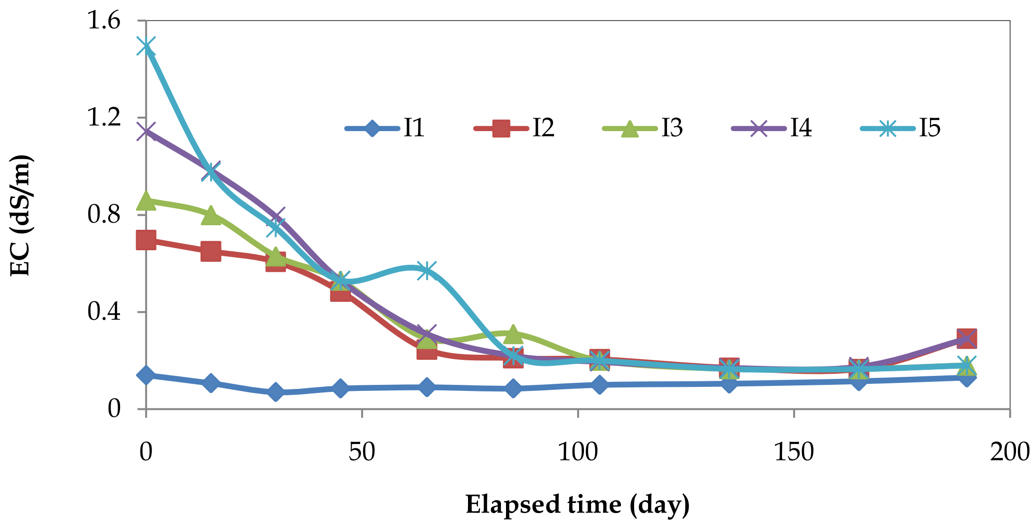

Fig.3.1. Salt leaching at 0-20 cm soil profile under different treatments.

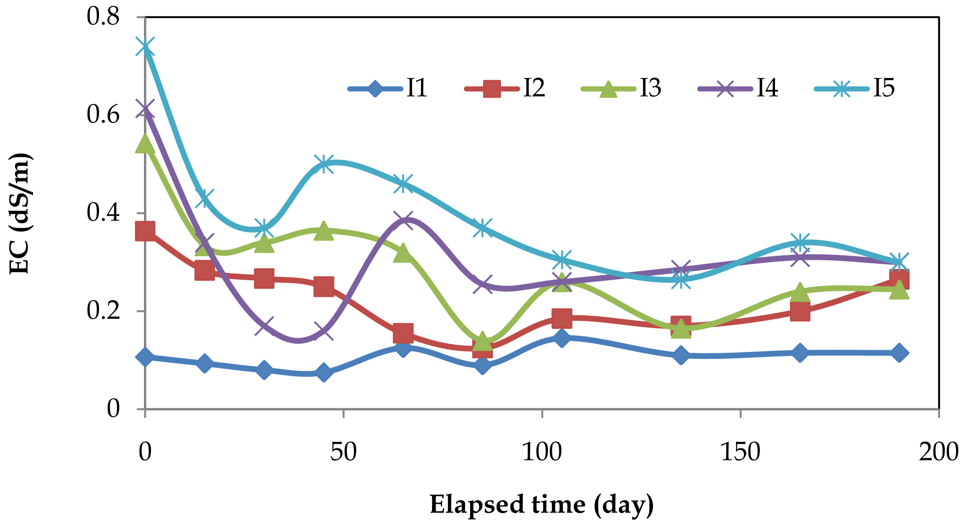

Fig.3.2. Salt leaching at 20-40 cm soil profile under different treatments.

An interesting observation in Fig.3.2 is that the salinity of the treatments I_2-I_5 increased considerably for some time after an initial rapid reduction. This was due to the fact that, after a few initial rainfalls, some salt leached rapidly from the soil profile. This salt from the upper soil profile (0-20 cm) leached down and elevated the salinity of the 20-40 cm soil profile. At the end of the rainy season, the salinity in this soil profile did not reduced to its initial value, implying that the rainfall was not enough to wash out the imposed salinity in the soil. A different scenario was however observed for the 40-60 cm profile as illustrated in Fig.3.3.

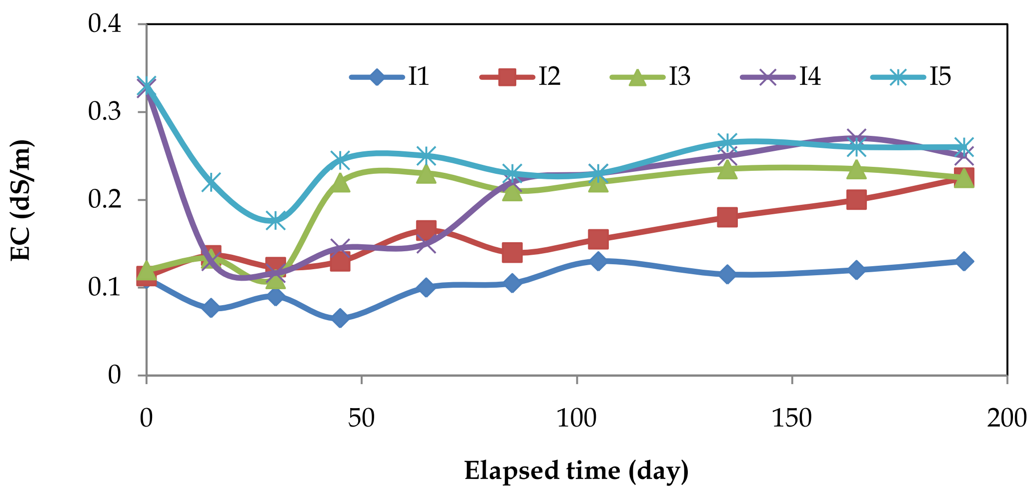

Fig.3.3. Salt leaching at 40-60 cm soil profile under different treatments.

This figure demonstrates that the treatments I_2-I_5 had high salinity, which decreased with time due to rainfall-induced leaching. Similar to the upper soil profile (20-40 cm), the salinity in I_3-I_5 initially decreased rapidly and then increased, first rapidly and then gradually. This finding implied that salt from the upper soil profiles continued accumulating in 40-60 cm soil profile. The salinity level in none of the salinity treatments (I_2-I_5) reduced to the non-saline level.

Fig.3.4 illustrates a comparison between salt leaching of different treatments and accumulated rainfall. Comparing the amount of rainfall and EC reduction, it is observed that, though, at early period, the rainfall was relatively little but the EC reduction rate was high, especially in the soil of high salinity (treatments I_4 and I_5) but at the late period, the EC reduction was relatively low with high rainfall. The salt leaching pattern with rainfall at the other soil layers were similar.

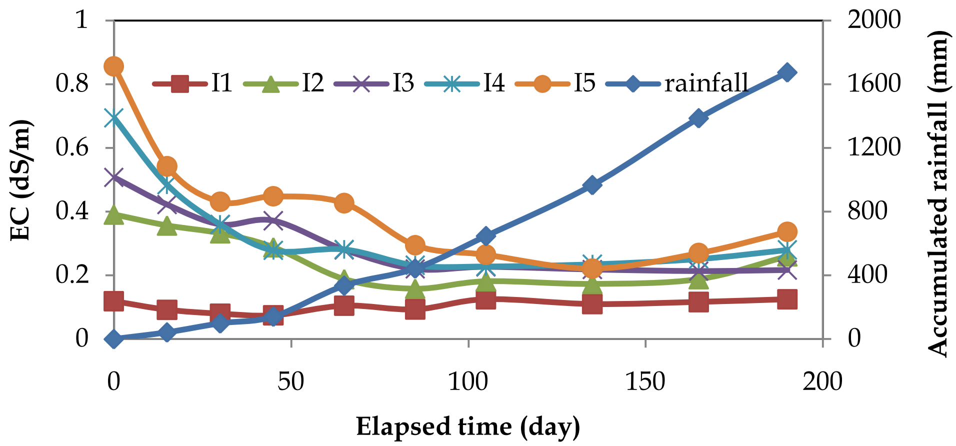

Fig. 3.4. Variation of salt leaching under different treatments with accumulated rainfall.

Depth variation of salt leaching

Salt leaching through different soil layers in treatment I_1 is illustrated in Fig.3.5. In this non-saline treatment, soil salinity at all three soil profiles (0-20, 20-40 and 40-60 cm) were same and they practically remained unchanged due to the effect of rainfall. The measured salinity in this treatment arises due to antecedent chemical compounds and clay in the soil.

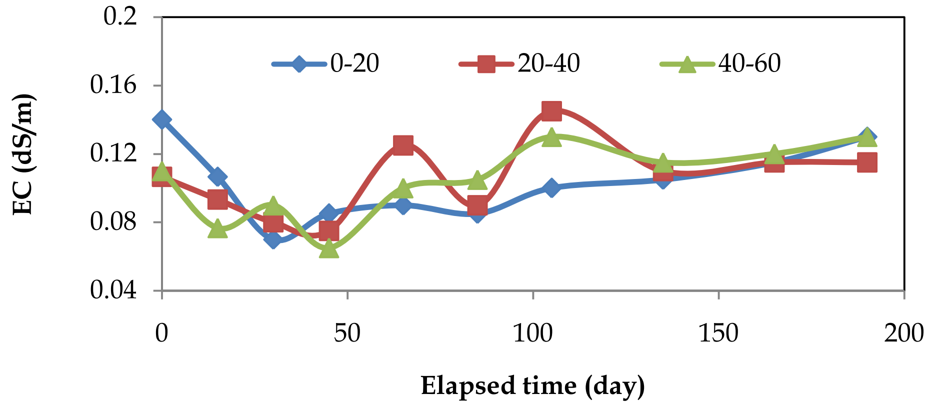

Fig.3.5. Variation of salt leaching through different soil layers in treatment I_1.

Unlike treatment I_1, the depth-variation of soil salinity is remarkable in this treatment I_2 as displayed in Fig.3.6. The salinity in treatment I_2 was relatively low. In the two upper layers (0-20 cm and 20-40 cm), soil salinity decreased and got reduced to the non-saline level.

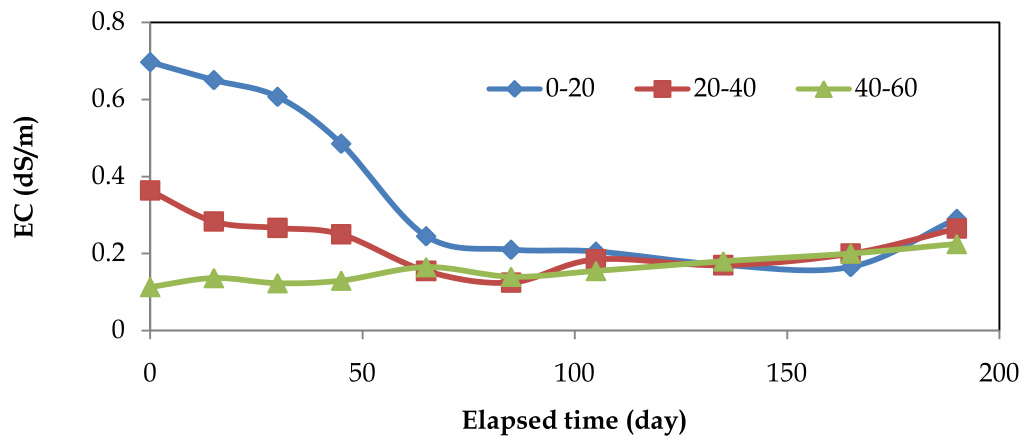

Fig.3.6. Variation of salt leaching through different soil layers in treatment I_2.

Figure 3.7 visually compares the salt leaching pattern through different layers in treatment I_3. The variation of soil salinity in I_3 was similar to that in I_2. The soil salinity in the upper two soil layers decreased quite rapidly first, but it then prolonged over time and never reduced to the non-saline level. The salinity at the 40-60 cm soil layer was much lower than the two upper layers. This salinity increased as the leached out salt from the upper soil profiles accumulated in the bottom layers.

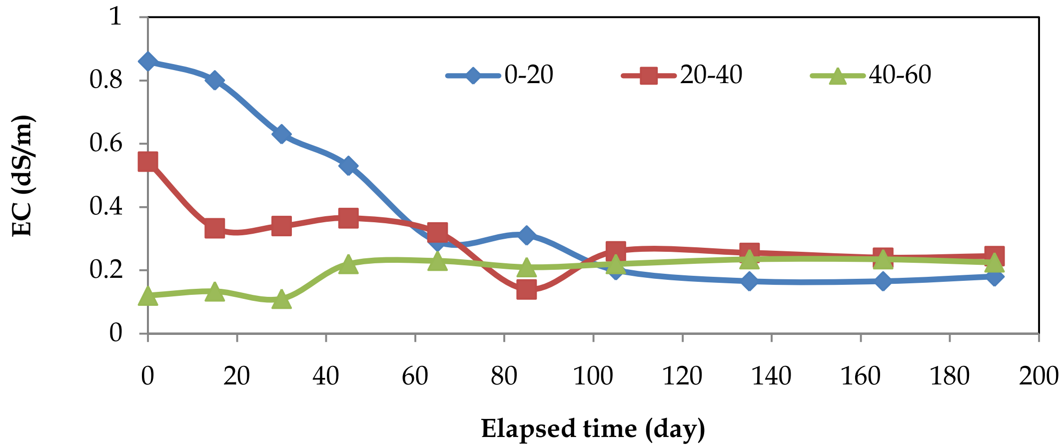

Fig.3.7. Variation of salt leaching through different soil layers in treatment I_3.

For I_4, the pattern of salt leach through different soil profiles is illustrated in Fig. 3.8. The salinity of the upper soil layers was higher than the lower layers at the beginning of the leaching period.

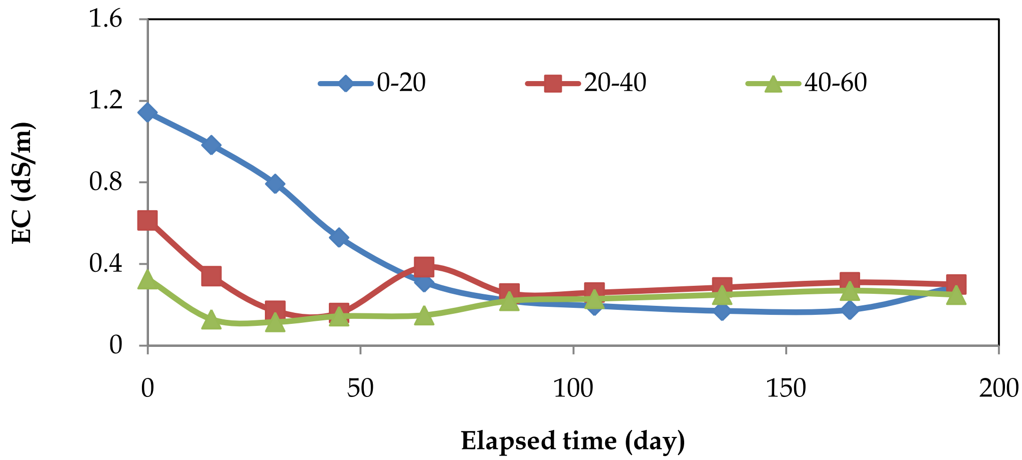

Fig.3.8. Variation of salt leaching through different soil layers in treatment I_4.

The variation of salinity in I_4 was similar to that in I_2 and I_3. The salinity in the upper two soil layers decreased rapidly first, but it then remained practically unchanged over time and never reduced to the non-saline level. As displayed in Fig.3.9, salt leaching through different soil layers in treatment I_5 was similar to that in I_2-I_4.

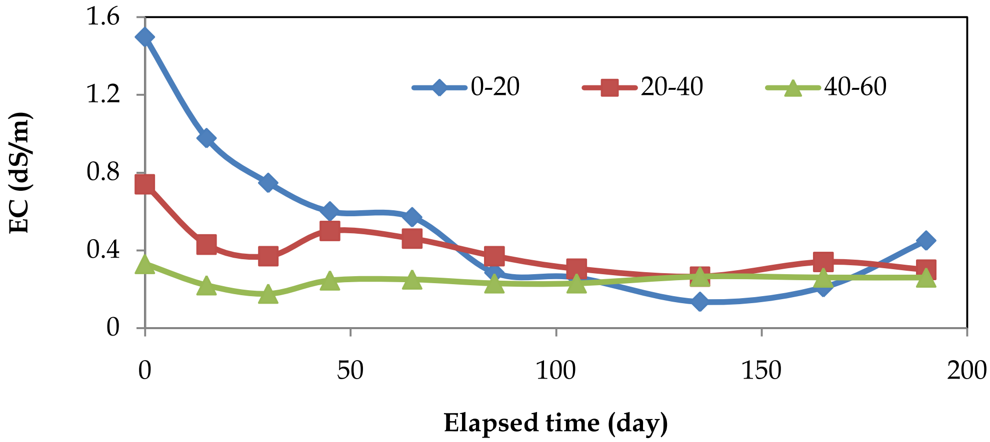

Fig.3.9. Variation of salt leaching through different soil layers in treatment I_5.

In all treatments, the initial salinity at the beginning of leaching period was much higher in the top layer than in the lower layers. Fig.3.10 compares the salt leaching pattern at different soil layers of treatment I_5 with rainfall. In all three soil layers, salt leached out rapidly at the early stage of leaching but slowly at the later stage. After certain period, leaching of salt did no more occur although there was enough rainfall. This implied that irrigation with high saline water caused accumulation of salinity in excess of that washed out by monsoon rainfall.

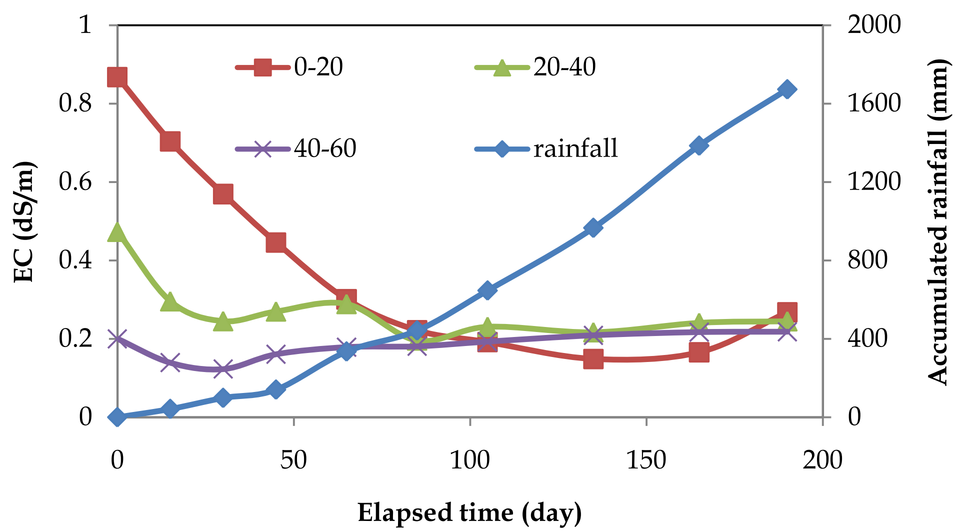

Fig.3.10. Comparison of EC through different soil layers in treatment I_5 with rainfall.

Residual soil salinity

After the rainy season, different salinity levels in the soil were obtained in the treatments at different depths.

Table 3.3. Comparison of initial and final soil salinities.

T*	AS*	Soil EC (dS/m) at depth					
		0-20 cm		20-40 cm		40-60 cm	
		I*	F*	I*	F*	I*	F*
I_1	0.13	0.14	0.13	0.10	0.15	0.11	0.13
I_2	0.29	0.69	0.29	0.36	0.26	0.11	0.22
I_3	0.18	0.86	0.18	0.54	0.24	0.12	0.22
I_4	0.29	1.14	0.29	0.61	0.30	0.32	0.25
I_5	0.18	1.50	0.18	0.74	0.30	0.33	0.26

*[T= Treatments, AS=Antecedent salinity (dS/m), I=initial, F=Final]

From the comparison of initial and final soil salinities (Table 3.3), it was observed that monsoon rainfall washed out the salt completely from the plots with relatively low salinity (I_2 and I_3) but not the plots with high salinity (I_4 and I_5).

Variation of soil pH

Soil pH was relatively stable. No remarkable variation due to rainfall was found compared to the initial and final soil pH of the plots. Soil pH increased to some extent (Table 4.5), but it showed no systematic relation with rainfall.

Table 3.4. Variation of soil pH in different treatments due to rainfall.

T*	A. pH*	Soil pH at depth					
		0-20 cm		0-20 cm		0-20 cm	
		I*	F*	I*	F*	I*	F*
I_1	7.89	7.89	8.41	7.96	8.42	8.13	8.41
I_2	7.88	7.88	8.54	7.87	8.34	8.11	8.43
I_3	7.99	7.99	8.48	8.12	8.51	7.96	8.32

I_4	7.79	7.79	8.43	7.82	8.31	7.91	8.28
I_5	7.65	7.65	8.40	7.92	8.32	7.96	8.32

*[T= Treatments, AS=Antecedent, I=initial, F=Final]

Conclusion

From the results of this study the following conclusions were drawn:

(i) At the end of the rainy season, the salt accumulated due to irrigation completely leached out of the top soil profile in all treatments.

(ii) Salinity at the lower layers was not leached out completely.

(iii) Soil salinity in the upper soil layers decreased rapidly than the lower layers.

(iv) Salinity at the lower layers increased as the leached out salt from the upper soil profiles accumulated in the lower layers.

(v) Irrigation with high saline water (≥7 dS/m) caused accumulation of salinity in excess of that washed out by monsoon rainfall.

High saline water (≥ 7 dS/m) is recommended to be avoided for irrigation.

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Conflicts of Interest

There are no conflicts to declare.